International Textile and Apparel Association (ITAA) Annual Conference Proceedings

2013: Regeneration, Building a Forward Vision

Jan 1st, 12:00 AM

Exploring a Process: Using Technology to Define Firefighter Glove Fit Preference

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Keywords: 3D hand scans, firefighter gloves, dexterity, fit

The aim of this study was to develop methodologies for a replicable process to scan bare and gloved hands and evaluate the fit of a structural firefighter glove model using a Human Solutions Vitus Head scanner. Our analysis was grounded in a literature review and findings from two focus groups of fire fighters in New York State. In our charge to deliver a replicable process to generate 3D anthropometric data, the study identified changes to the current glove model that could be implemented immediately to improve dexterity, and future areas to research for long-term enhanced fit and sizing of this glove model.

Review of Literature

Research on glove fit and anthropometric data on structural firefighter gloves is limited, thus the research scope was expanded to include non-firefighter specific personal protective equipment literature. Key findings from the literature identified fundamental hand measurements that are important to developing glove patterns while considering differing hand dimensions across gender and ethnicity (2009). Pine (1991) who analyzed the fit of structural firefighter gloves with 90-day wear trials, found the finger lengths and crotch depths of the gloves disproportional to the ungloved hand. Our study supports fit issues found in both the agricultural literature and military anthropometric studies (Department of Defense, 1991).

Data Collection

Consumer preference data were collected through two focus groups with firefighters in New York State. Twelve focus group participants substantiated data from the literature on glove fit and dexterity issues. As was anticipated, firefighters generally found gloves constructed with a 3D anthropomorphically correct shape allowed for better dexterity than gloves that are constructed in a flat 2D orientation. Lack of clarity on correct sizing also contributed to reduced dexterity. Our participants indicated that oftentimes a "tradeoff" must be made between dexterity and protection. The tradeoff decision is usually made based upon the job description of the specific fire fighter. For example, a hose operator might compromise protection for dexterity, whereas firefighters who go inside buildings and are proximally closer to flames sacrifice dexterity for protection. Through the focus groups, we were able to isolate the problems of fit and dexterity issues for further development of the scanning and glove analysis process.

Process Development and Testing

Concurrent to the focus groups, a process to scan hands was developed utilizing technology available through the Cornell Body Scan lab. The process was piloted twice by scanning the dominant hands of both a male and female participant. Several biomechanically correct hand positions for dexterity were tested, but were ultimately eliminated from the study due to excessive variation in the hand position. Such inconsistency and variation precluded successful overlaying of the bare and gloved hand images. A quality scan that allowed for consistency in hand position from bare to gloved hand was achieved where flexion and extension

on the sagittal plane of the wrist was neutral with no ulnar or radial deviation. A sheet of plexiglass of 1/4" maximum thickness proved adequate to stabilize the hand and minimize unintentional movement, while providing consistency in hand position and angle. Once the subject aligned his/her hand with the paper template, which provided consistent finger spread, the template was removed to avoid interference with the image capture of the hand scan.

Findings

The scans were converted to 3D images using GeoMagic software and overlayed in Polyworks. Through the 3D visualization process, the bulk located between each finger and at the finger tips, which can be attributed to the triple layer construction of structural firefighter gloves, became evident. Overlay of the bare and gloved hand images also indicated a large amount of ease over the knuckles, which is material that allows the hand to move when performing gripping tasks. The visualization also revealed that the crotch length of the gloves was not in proportion with the finger lengths, which was most evident in the pinky. Torrens and Campbell (2012) support this observation where they confirm the crotch length measurements as critical dimensions to ensure effective hand wear for military gloves.

Future Research

As was evident from the review of literature, firefighter focus groups, and analysis of scan overlay data, we suggest further investigation into the relationship of the finger lengths and crotch depths of the gloves. Clear and consistent 3D scans are a helpful tool in visualizing the hand to glove relationship. Areas of glove redesign were communicated to the manufacturer to provide immediate improvement of the glove model including suggestions to reduce bulkiness between each finger due to the three layer glove design. Evidence of the importance of the relationship between the finger length and crotch depth were also conveyed to the manufacturer through 3D visualization of the bare hand and glove overlays.

Future research into improving the hand scanning process should include further investigation into perfecting the hand stand apparatus for greater consistency in hand positions. As the base process is now established, using hand scanning technology is much more efficient and consistent than manual measuring techniques used elsewhere in the literature. Because firefighters perform several unique tasks, it is important to identify the most common anatomical hand positions for the target population, scan consistently while in those positions, and critically examine glove fit. Further research with the target population will provide concise 3D anatomical data to revise glove pattern and construction, and in turn increase consumer satisfaction.

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